Implementation of a Robot Behaviour Learning Simulator

Kushagra Singh Bisen

Ecole des Mines de Saint Etienne

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Overview

Context and Motivation

Lab Overview

- Department of Computing and Intelligent Systems is situated in Institut Henri Fayol, EMSE.
- The department aims to develop algorithms and architectures for the interconnection of physical, digital and social worlds.
- The interconnection takes in account of all the dimensions neccesary for the deployment of applications in Industry 4.0 and Smart Cities.
- The department's research interests lie in knowledge representation, reasoning, multi agent system, data mining and security.

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Motivation

- The work is based in an Industry 4.0 scenario.
- There are various entities in the environment, both mobile and static.
- We wish to study and record the behaviour of the robot while it moves.
- The behaviour of the robot is used to detect and prevent collisions.
- The work will be included in the Set of Intelligent Robots project at Institut Henri Fayol.

Robot

- A system with decision making capabilities.
- A Cyber-Physical System (CPS) combining sensing, actuation and computation.
- Perform Dirty, Dull or Dangerous tasks.
- Various applications, as *mobility on demand*, *drone servillance*, *long distance logistics* and *automated highways*

Essential Qualities of Robot

Autonomy is essential for a system to be called a robot. Autonomy is achieved through,

- Perception : employing *proprioceptive sensors* and *exteroceptive sensors*
- Action : calculation of velocities to move in a direction.
- Decision Making : Utilizes previous modules to result in *navigation*

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Digital Twins

- Model an Industry 4.0 process/machine.
- Enabling testing, training and error detection before real-life implementation.
- Defined as machines which are simulating, mirroring, and "twinning" a physical entity.
- It can be linked to a *physical twin* [B. R. Barricelli, E. Casiraghi and D. Fogli, 2019]
- It is not a **simulation** but an exact replica of it's **physical twin**.
- enabling communication-collaboration-interaction with PT (physical twin)
- a part of Cyber-Physical Systems.

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Behavioural Learning

- Learning the behaviour of the robot in the space.
- The behaviour of the robot can be learnt by it's position as well as it's position relative to the obstacles.
- The behaviour of the robot is used for reinforcement learning.

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Objectives

Implementation Questions

- How can we make the robot move from a position to the other?
- How can we represent the configuration space in simulator?
- Which data can *we use/not use* for behaviour learning?
- Which method we can use for behaviour learning?

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Implementation

Technologies

- **Turtlebot** : Personal robot kit with LIDAR sensor running on open-source software.
- **Gazebo Simulator** [Koenig, N. and Howard, A.] : Used to visualise the Turtlebot and the environment generated by 3D models.
- **Robot Operating Systems** : flexible framework which provides abstraction, libraries, drivers, package management.

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Simultaneous Localization and Mapping (SLAM)

- Technique for self-exploration of the environment.
- Fundamental requirement for an autonomous system.
- Combines two different technologies, i.e Localization and Mapping.
- It is done concurrently as the robot moves.

Features of SLAM

- **Localization** : Using odometry information of the robot to estimate the position in environment.
- **Mapping** : Using the LIDAR sensor to register information (obstacles and position) about the environment producing a map file.

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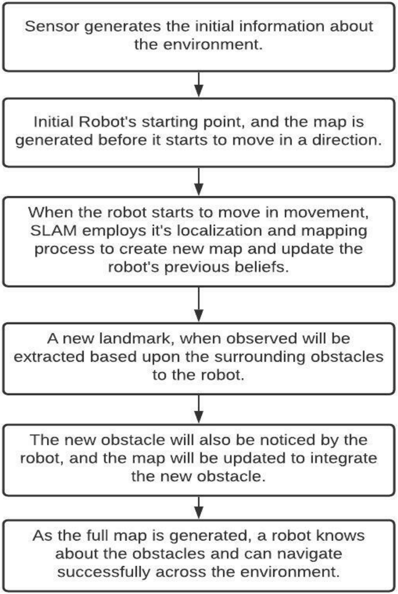
SLAM Workflow



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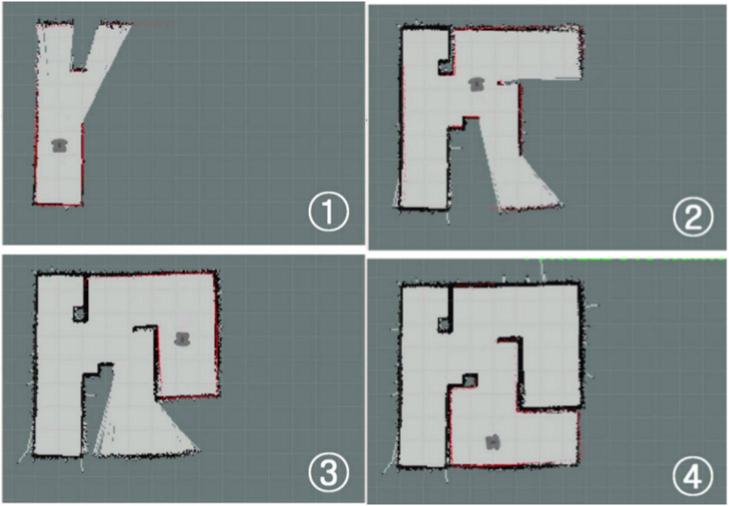
Step-By-Step SLAM

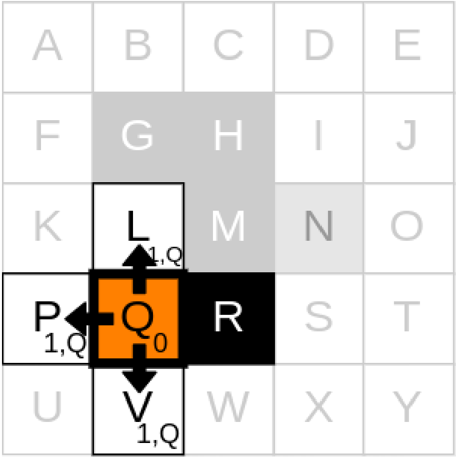


Path Planning Algorithms

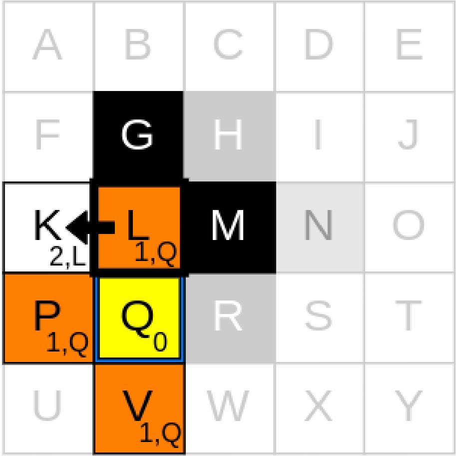
Path Planning Algorithms provide methods to execute planning to the goal state. They are of two types :

- *Global Planner Algorithms* : Offline algoritms to calculate further states of the robot. Implemented algorithms are, *Dijkstra*, *A** and Greedy Best First Search Algorithm.
- *Local Planner Algorithms* : Online dynamic algoritms to calculate the path while the robot is moving. Implemented algorithm is, *Dynamic Window Approach Planner*.

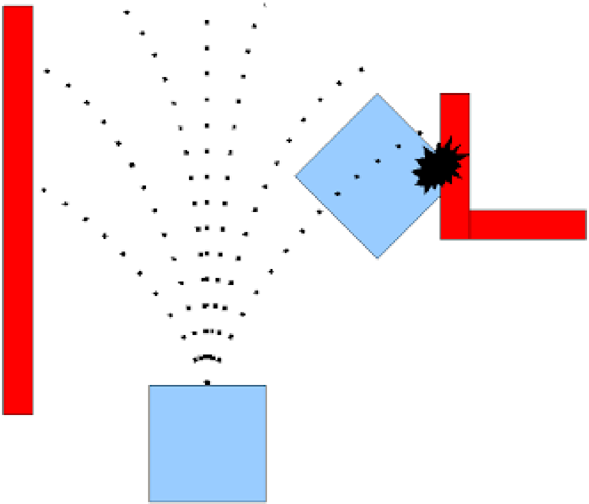
Exploration Stage 1



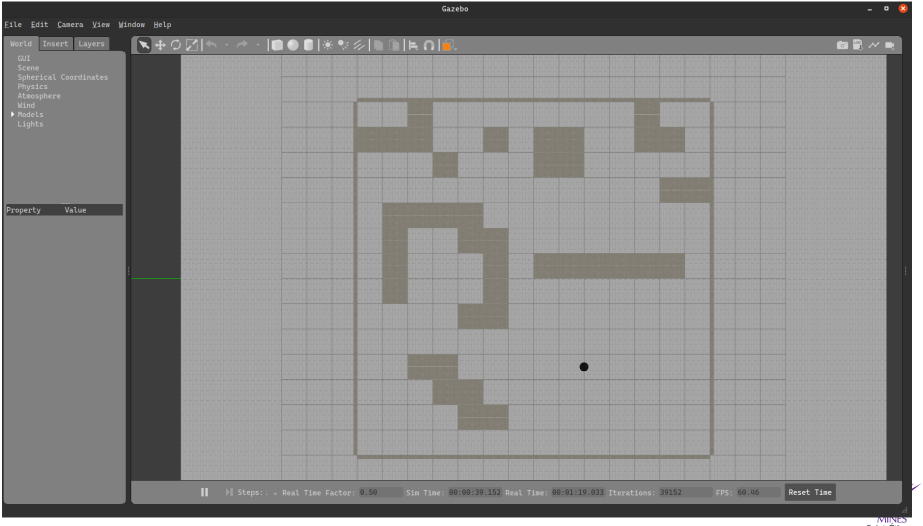
Exploration Stage 2



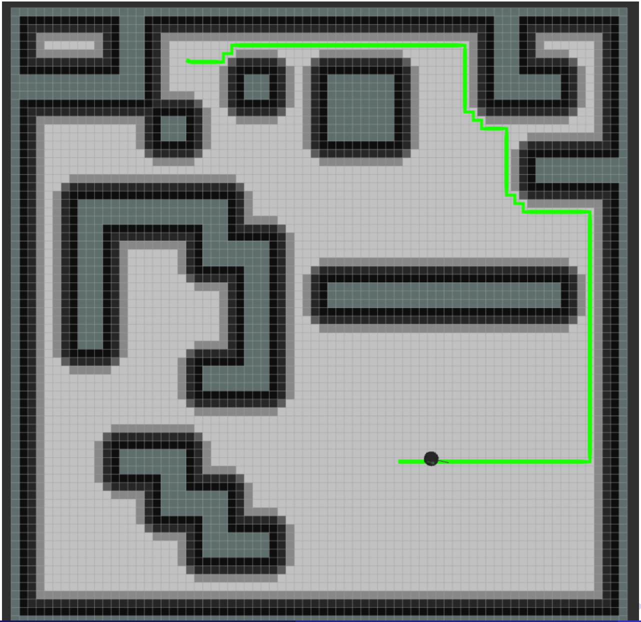
Dynamic Window Approach Algorithm



Navigation Implementation

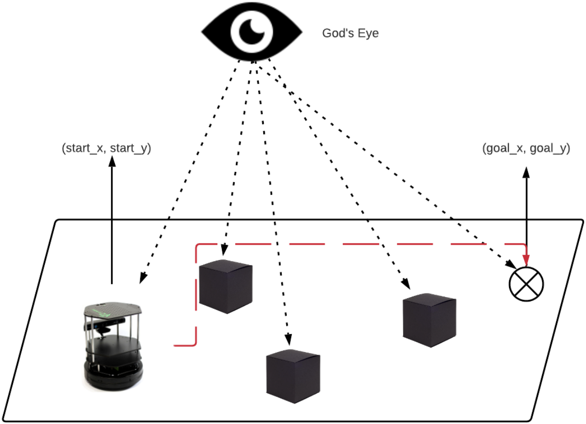


Navigation Implementation (Contd.)



Method for Behaviour Learning

The hypothesis is to use the digital twin made to store the information related to the state and neighborhood of the robot by *God's Eye*

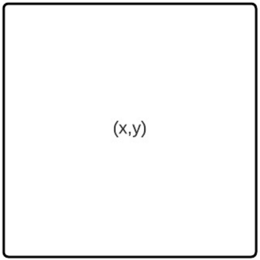


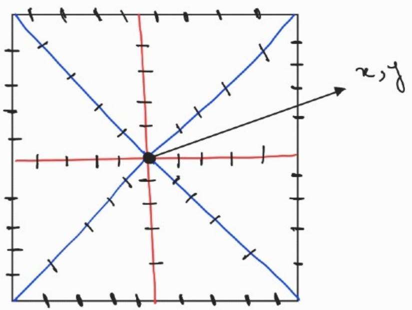
Method (Contd.)

- Each obstacle is represented by a pair of x and y coordinates.
- The x and y coordinates of robot can be infered by odometry.
- A distance or a *fake perception range* is specified to construct the grid.
- Grid's positions are calculated by adding the perception range to the coordinate.
- If they are equal, an obstacle is recorded.
- The obstacle behaviour grid is record and stored.

Method (Contd.)

- We had to divide the obstacle coordinate into more coordinate points for better accuracy in the grid space.
- One obstacle is represented by not one, but 72 coordinate points.
- The individual grid size is 0.1, and it can be changed as per the requirement.
- The grid space calculated is of sizes 3 by 3, 5 by 5, 7 by 7 and further with the robot in middle.
- Bigger Grid Size shows better information of the robot's space.





Generated Log

The generated log file in semi structed data format contains,

- Timestamp in seconds.
- x, y coordinates of the robot.
- obstacle grid.
- x,y coordinates of the goal.
- relative coordinates to the goal.
- manhattan distance to the goal.
- euclidian distance to the goal.
- angular rotation of the robot.

Conclusion

Conclusion

To summarize, we developed

- a digital twin for autonomous behaviour of robot by avoiding obstacles to a goal.
- a method for generating a static grid for neighborhood space.

On-going and future work,

- Implementing the method in different scenarios of the environment.
- Implementing multiple robots to form a multiple robot system and recording behaviour for each.
- The recorded behaviour can be used for machine learning, training, and testing to develop stratey with digital twins.
- Robot's arm i.e a Manipulator's Behaviour can be studied in future.

Thank you for your time.

References

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Design and use paradigms for Gazebo, an open-source multi-robot simulator

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